

Using a Scanning Electron Microscope to Study Properties of an APS Detector

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A new proposal [1] to build a Heavy Flavor Tracker (HFT) for the STAR experiment at RHIC has just been submitted. The HFT will bring new physics capabilities to STAR, including identification of particles with charmed or bottom quarks.

The HFT uses an Active Pixel Sensor (APS) to detect charged particles. When a charged particle interacts in an APS sensor, it deposits charge in the middle epitaxial layer. This charge then diffuses to nearby n-diodes which are regularly spaced. Details of this sensor have been discussed in previous publications. [2]

Using Berkeley Lab's Scanning Electron Microscope, we studied the response of a detector with 20 μm diode spacing to electrons from 5 to 30 keV. An image of the detector is shown in Fig. 1. This picture clearly shows 20 μm lattice spacing, which is the same periodicity as sensor. While it is not a true image of the structure on the IC, it does reflect the electrostatics of the sensor and can be used to probe individual pixels. Using this image and the observation of the pixels with the APS read out electronics, we were able to position the beam to a specified location.

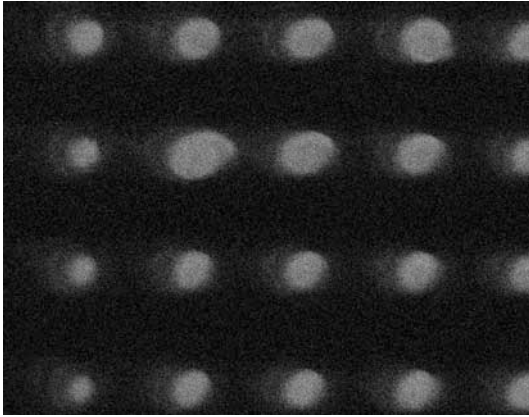


FIG. 1: Electron Microscope picture of the APS chip. The structures are spaced at 20 μm .

At each electron microscope position, we measured the charge deposited into each pixel. We then extracted the position by using several algorithms for the highest pixel x_2 and its neighbors x_1 and x_3 . The results in the x-direction are shown in Fig. 2. The most linear algorithm is the third – $(x_3 - x_1)/(x_1 + x_2/2 + x_3)$. As expected, we found similar results for the y-direction.

Initially, we thought that there were only 2 μm of material in front of the epitaxial layer and so the electron beam could penetrate it and deposit most of its energy. However, when we tried to understand the energy distribution, we discovered

that we measured much less than 25 keV for a single incident electron. To solve this mystery, we decided to measure the layers of the APS chip using a beam of Ga^+ ions to mill a small hole in the sensor and a high resolution field emission electron beam microscope to identify the elements in the image. This analysis showed that the chip had an unexpected 11.6 μm amount of material above the epitaxial layer.

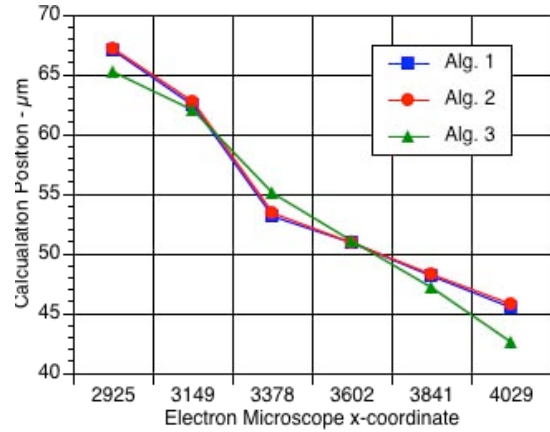


FIG. 2: Electron microscope position versus the calculated position. For the charge collected in three successive pixels, x_1 , x_2 , and x_3 , algorithm 1 is $(x_3 - x_1)/(x_1 + x_2 + x_3)$; algorithm 2 is $x_3/(x_2 + x_3) - x_1/(x_1 + x_2)$, and algorithm 3 is $(x_3 - x_1)/(x_1 + x_2/2 + x_3)$.

As electrons at 25 keV only have a range of several microns in silicon, then we must have detected the bremsstrahlung from the electrons. Using a very simple calculation, we find that the centroid of the distribution coincides with the initial electron position and the width matches what we observed. Unfortunately, this width is about the size of a pixel, so precise position studies are difficult.

In summary, we have shown that a scanning electron microscope can be used to study algorithms to measure the incoming position of charged particles on an APS IC.

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REFERENCES

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- [2] H. S. Matis *et al.*, *Charged particle detection using a CMOS Active Pixel Sensor*. IEEE Trans. Nucl. Sci. **50**, 1020 (2003).